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IMAGING VIGNETTE

Anatomy of Pulmonary Veins by Real-Time 3D TEE

Implications for Catheter-Based Pulmonary Vein Ablation

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REAL-TIME 3-DIMENSIOANL TRANSESOPHAGEAL ECHOCARDIOGRAPHY (RT3DTEE) provides high quality images of the posterior structures of the heart (1) and has been used for guiding several catheter-based procedures (2).

The electrical isolation of pulmonary veins (PVs) has become a highly effective treatment option for symptomatic, drug-resistant atrial fibrillation (AF). RT3DTEE may potentially represent a novel monitoring modality for anatomy-driven PVs isolation. However, a standardized RT3DTEE protocol for imaging acquisition and processing of PVs is lacking. We describe a systematic step-by-step approach of acquisition modality of each PV by RT3DTEE, their normal appearance, comparison with equivalent

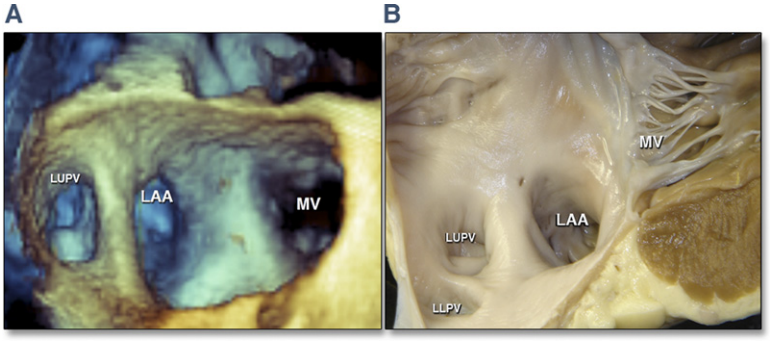

Figure 1. Left Upper Pulmonary Vein

The easiest way to visualize the left upper pulmonary vein (LUPV) is using the zoom mode directly towards the left atrial appendage (LAA). Once the LAA is seen, a slight counter clockwise rotation of the probe allows the LUPV ostium to be imaged "en face." **(A)** RT3DTEE of the LUPV and **(B)** the corresponding anatomic specimen. LLPV = left lower pulmonary vein; MV = mitral valve.

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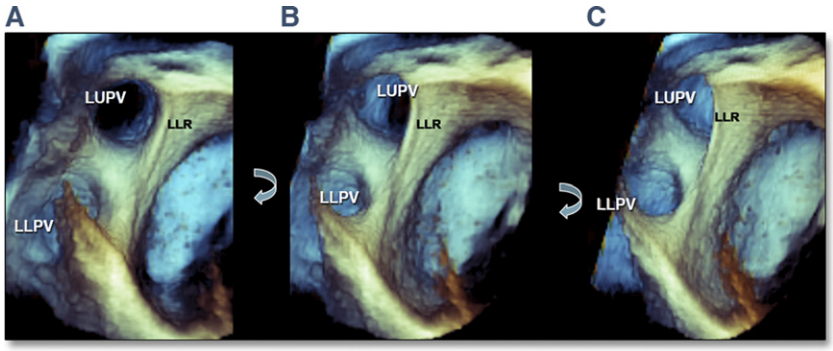

Figure 2. Left Pulmonary Veins

The LLPV is more difficult to visualize. A perfect side-by-side "en face" view of both ostia is difficult to obtain from a unique perspective because of their oblique directions. However, when both ostia are inside the pyramidal dataset, a gentle angulation of the 3-dimensional pyramidal data set, may visualize first the upper and then the lower pulmonary vein. **(A)** Shows both the LUPV and LLPV. The ostium of the LLPV is partially covered by surrounding structures while the ostium of the LUPV is well defined. **(B to C)** A slight right-to-left rotation of the image **(curved arrows)** allows a better visualization of LLPV ostium, while part of the LUPV ostium is covered by the left lateral ridge (LLR). Abbreviations as in Figure 1.

anatomic specimens and examples of its use during catheter-based PV ablation. Images were acquired using a Philips IE 33 (Philips Medical System, Andover, Massachusetts) equipped with real-time transesophageal transducer and processed using Q lab software (Philips Medical System).

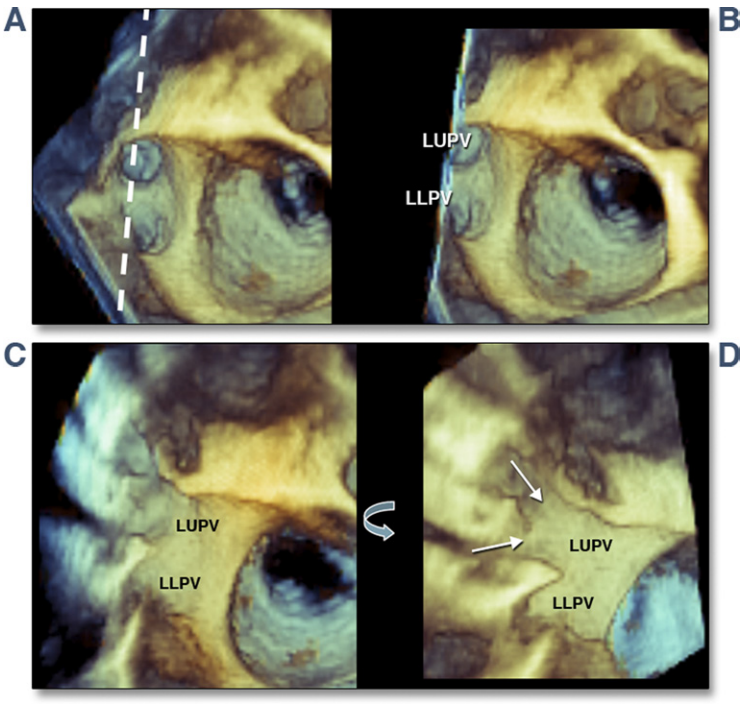

Figure 3. Left Pulmonary Veins Visualized in Long Axis View

(A) A longitudinal cut through the middle of the pulmonary venous lumens (dotted line). **(B)** Half of the wall vein is then "electronically" removed. **(C to D)** A 90° left-to-right rotation of the image **(curved arrow)** reveals the lumens of both LUPV and LLPV in their long axis orientation. A confluence of 2 branches of LUPV is also displayed **(arrows)**. Abbreviations as in Figure 1.

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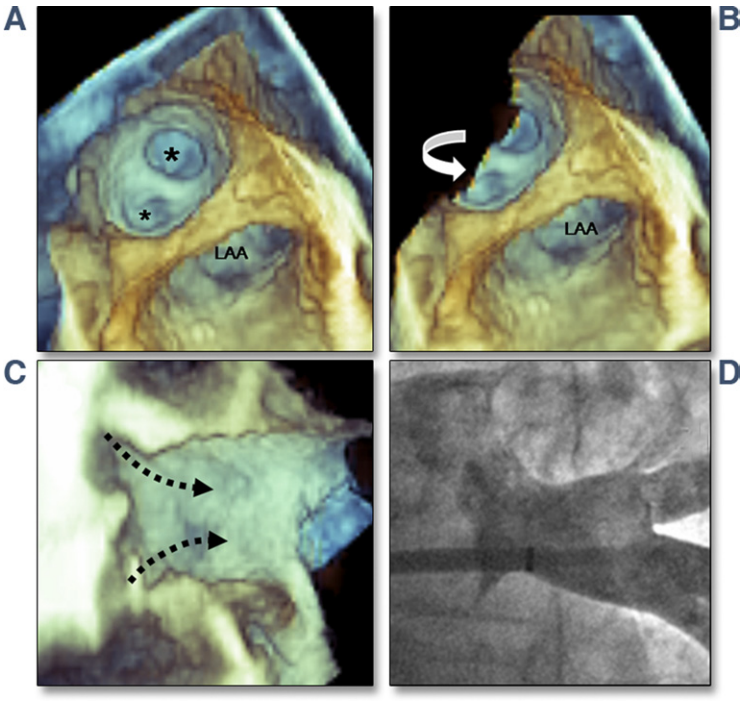

Figure 4. Common Left Pulmonary Vein

(A) A large ostium of a single left pulmonary vein from "en face" perspective. Two secondary ostia are visible deep inside the lumen **(asterisks)**. **(B)** Half of the venous wall is removed by an oblique cut. **(C)** A 90° left-to-right rotation of the image shows a common vein and its branches in a long axis orientation. **(D)** The angiographic view of the same patient. LAA = left atrial appendage.

Theoretically, 3-dimensional imaging of the roof of the left atrium should be able to visualize all of the 4 PVs' ostia in a single image. However the right and left pairs of veins are widely separated and lie very close to the transducer. At this transducer distance, the pyramidal beam is too narrow to visualize the

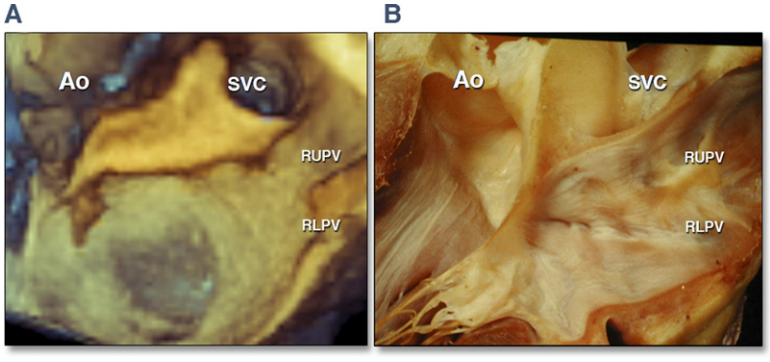

Figure 5. Right Pulmonary Veins Visualized in Long Axis View

An approach to visualize the right pulmonary veins is that used to visualize the atrial septum in "en face" view. From this view the right pulmonary veins run adjacent to the septum but, being covered by surrounding structures, they cannot be seen. **(A)** A crop of the surrounding structures by advancing Y-plane box reveals the lumens of both right upper pulmonary veins (RUPV) and right lower pulmonary veins (RLPV) in their long axis orientation. **(B)** Anatomic specimen displayed in an equivalent perspective.

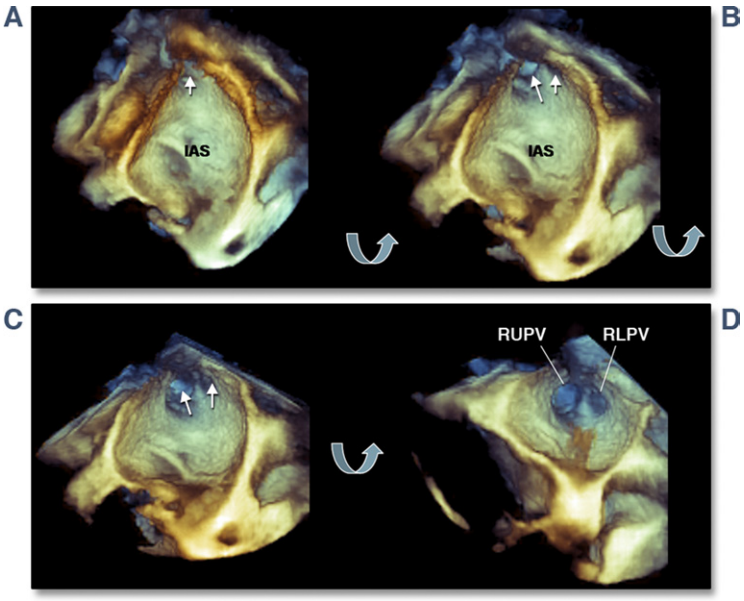

Figure 6. Ostia of Right Pulmonary Veins

(A) Shows the same perspective as Figure 5. **(B to D)** A progressive rotation of the image **(curved arrows)** reveals the side-by-side arrangement of both RUPV and RLPV ostia in an "en face" perspective. Abbreviations as in Figure 5.

entire roof of the left atrium together with the PVs. Thus, the left and right PVs must be visualized separately. Images of left and right PVs in different views are presented in Figures 1, 2, 3, 4, 5, 6, and 7; images of the lateral ridge are presented in Figures 8 and 9. Finally, an example of a case of isolation of left and right upper PVs is shown in Figures 10 and 11.

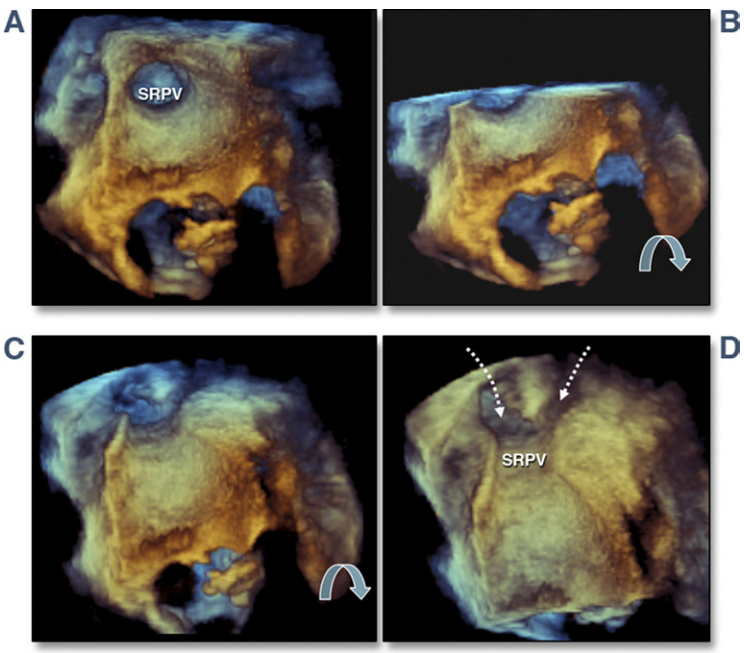

Figure 7. Common Right Pulmonary Vein

(A) Single right pulmonary vein (SRPV) "en face" view. **(B)** Half of the venous wall is removed by an oblique cut. **(C to D)** A slight left-to-right rotation shows the single vein and its branches in an oblique/long axis orientation.

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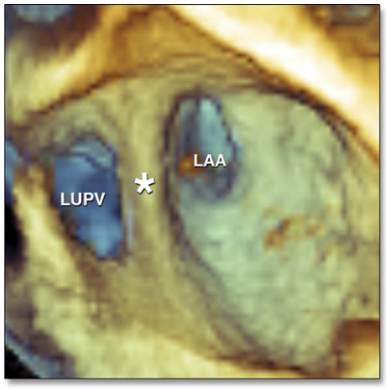

Figure 8. The Left Lateral Ridge

Using an "en face" perspective, the left lateral ridge appears as a distinct structure of variable prominence **(asterisk)** that separates the LAA from the orifice of the LUPV. Abbreviations as in Figures 1 and 4.

As for other interventional procedures, it is reasonable to forecast that this technique may become a useful complementary imaging modality in anatomy-driven radiofrequency PV ablation, hopefully resulting in significant reductions of procedural and fluoroscopy time.

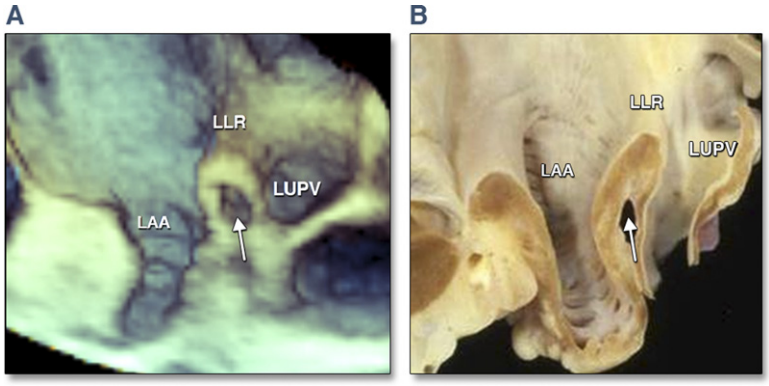

Figure 9. The Left Lateral Ridge in a Cross Axis View

(A) Real-time 3-dimensional transesophageal echocardiography (RT3DTEE) imaging of the LLR after a transversal cut showing that the ridge is actually an infolding of atrial wall **(arrow)**. **(B)** Anatomic specimen displayed in a similar perspective. Abbreviations as in Figures 1 and 2.

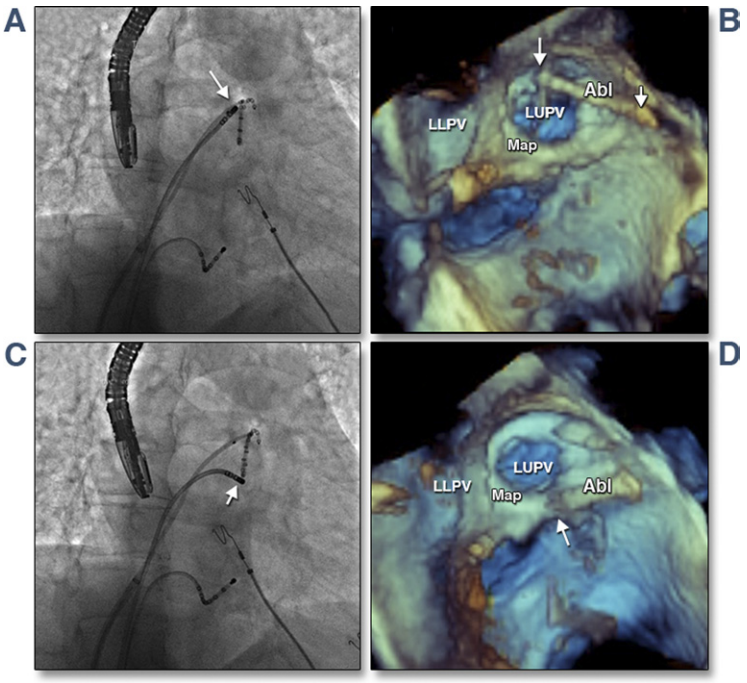

Figure 10. RT3DTEE-Driven Ablation of LUPVs

(A and C) Simultaneous fluoroscopic and **(B and D)** RT3DTEE imaging during LUPV isolation. The **arrows** in both fluoroscopic and RT3DTEE images indicate the contact between irrigated-tip ablation catheter (Abl) and the orifice of LUPV. MAP = circumferential pulmonary vein mapping catheter; other abbreviations as in Figures 1 and 9.

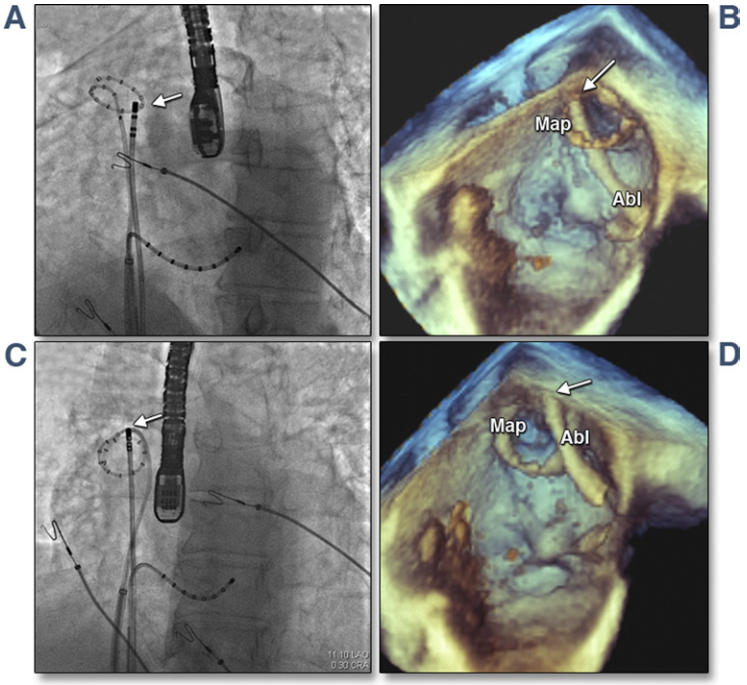

Figure 11. RT3DTEE-Driven Ablation of RUPVs

(A and C) Simultaneous fluoroscopic and **(B and D)** RT3DTEE imaging during RUPV isolation. The arrows in both fluoroscopic and RT3DTEE images point to the contact between irrigated-tip ablation catheter and the orifice of the vein. Abbreviations as in Figures 5, 9, and 10.

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